PROCEEDINGS

OF

THE ROYAL SOCIETY.

January 17, 1901.

Sir WILLIAM HUGGINS, K.C.B., D.C.L., President, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

The following Papers were read:—

I. "Total Eclipse of the Sun, January 22nd, 1898. Observations at Viziadrug.—Part IV. The Prismatic Cameras." By Sir NORMAN LOCKYER, K.C.B., F.R.S.

II. "Wave-length Determinations and General Results obtained from a Detailed Examination of Spectra photographed at the Solar Eclipse of January 22, 1898." By J. EVERSHED. Communicated by Dr. RAMBAUT, F.R.S.

III. "The Thermo-chemistry of the Alloys of Copper and Zinc." By T. J. BAKER. Communicated by Professor POYNTING, F.R.S.

"Mathematical Contributions to the Theory of Evolution. IX.—On the Principle of Homotyposis and its Relation to Heredity, to the Variability of the Individual, and to that of the Race. Part I.—Homotyposis in the Vegetable Kingdom." By KARL PEARSON, F.R.S., with the assistance of ALICE LEE, D.Sc., ERNEST WARREN, D.Sc., AGNES FRY, CICELY D. FAWCETT, B.Sc., and others. Received October 6,—Read November 15, 1900.

(Abstract.)

(1.) If we take two offspring from the same parental pair, we find a certain diversity and a certain degree of resemblance. In the theory

of heredity we speak of the degree of resemblance as the fraternal correlation, while the intensity of the diversity is measured by the standard deviation of the array of offspring due to given parents. Both correlation and standard deviation are determined for any given character or organ by perfectly definite well-known statistical methods. Passing from the case of bi-parental to asexual reproduction, we may still determine the correlation and variability of the offspring. This ultimately leads us to the measurement of the diversity and likeness of the products of pure budding, or, going still one stage further, we look, not to the reproduction of new individuals, but to the production of any series of like organs by an individual. Accordingly one reaches the following problem:—If an individual produces a number of like organs, which so far as we can ascertain are not differentiated, what is the degrees of diversity and of likeness among them? Such organs may be blood-corpuscles, hairs, scales, spermatozoa, ova, buds, leaves, flowers, seed-vessels, &c., &c. Such organs I term *homotypes* when there is no trace to be found between one and another of differentiation in function. The problem which then arises is this:—Is there a greater degree of resemblance between homotypes from the same individual than between homotypes from separate individuals? If fifty leaves are gathered at random from the same tree and from twenty-five different trees, shall we be able to determine from an examination of them what has been their probable source? Are homotypes from the individual only, a random sampling, as it were, of the homotypes of the race?

By the examination of very few series from the animal and vegetable kingdoms I soon reached the result, that homotypes, like brothers, have a certain degree of resemblance and a certain degree of diversity; that undifferentiated like organs, when produced by the same individual, are, like types cast from the same mould, more alike than those cast by another mould, but yet not absolutely identical. I term this principle of the likeness and diversity of homotypes *homotyposis*. It soon became clear to me that this principle of homotyposis is very fundamental in nature. It must in some manner be the source of heredity. It does not, of course, "explain" heredity, but it shows heredity as a phase of a much wider process —the production by the individual of a series of undifferentiated-like organs with a certain degree of likeness. My first few series seemed to show that the homotyposis of the vegetable and animal kingdoms had approximately the same value, and it occurred to me that we had here the foundation of a very widespread natural law. In order to demonstrate its truth, however, the homotyposis of a large range of characters in a great number of species must be investigated, and I soon found my own unaided efforts were quite unequal to the task of collecting, tabulating, and reducing the data. As the

material grew, it seemed desirable to separate the vegetable and animal kingdoms, and the present paper deals only with the former. In this field I have had the aid of a number of competent helpers. To collaborators who have long aided me, like Dr. Alice Lee, Miss C. D. Fawcett, and Mr. Leslie Bramley-Moore, I have been able to add, for the present purpose, Miss Agnes Fry, Dr. E. Warren, Dr. W. R. Macdonell, Miss M. Barwell and others, who have taken part in the labour either of collection, of measurement, or of computation. The result of this united labour is that twenty-two series, with upward of twenty-nine correlation tables, are here dealt with.* Small in number as this may seem, when we think of the vast variety of the vegetable kingdom, it means an immense amount of work—special series, which are in the memoir represented by a page of table and a few lines of numerical constants, have often cost one or other of us weeks of steady work. Hence I cannot strongly enough express my gratitude to my co-workers; they have more than ever convinced me of the great importance of co-operation for the future of scientific research, and the desirability, if possible, of organising the labour of isolated scientific workers. I will now indicate the general results we have reached.

(2.) The following series were dealt with: (1) to (3). The leaflets of the compound leaf of the Ash were counted in upwards of 300 trees from Buckinghamshire, Dorsetshire, and Monmouthshire. The results were in good agreement, and show homotyposis as a racial character of considerable constancy. (4) to (5) The veins in the leaf of the Spanish Chestnut were counted in 100 trees from Buckinghamshire and 100 trees of mixed character. Homotyposis was found to increase with heterogeneity of age and locality. (6) The veins were counted in the leaves of 100 Beech trees from Buckinghamshire. (7) and (8) The prickles were counted on the leaves of 100 Holly trees from Somersetshire and 100 from Dorsetshire. This completes the series of homotypes for trees. The tree results are in fair accordance, when we allow for the disturbing factors of environment, age, and personal selection. (9) to (13) We next investigated five series of Poppies, counting the stigmatic bands on the seed-capsules; *Papaver Rhœas* for three series, from top of Chilterns, bottom of Chilterns, and the Quantocks; Shirley Poppies for two series from Great Hampden and Chelsea. The results were again in fairly reasonable accordance with each other and with those for trees. (14) and (15) The segmentation of the seed vessels was counted in *Nigella Hispanica* and *Malva Rotundifolia*; the homotyposis was found to be much weakened, but actual differentiation was observed between the seed vessels on the main stem and on the side shoots of the former, and the 127 plants of the latter had principally arisen by stolons from a single clump, and were not thus entirely independent individuals. (16) The members of the whorls were counted

* In the Appendix an additional fifteen series will be found.

in 201 sprays from separate plants of *Asperula odorata;* it was known that these members are differentiated in their origin; the homotyposis was found much weakened. (17) and (18) The *sori* on the fronds of 100 Hartstongue ferns and the lobes on the fronds of 100 plants of Ceterach were counted. We were told that these characters are much affected by age of plant and environment of individual; we found the homotyposis increased very sensibly beyond the value obtained for trees. (19) The veins in the tunics of 200 examples of *Allium cepa* were counted. (20) The seeds in the pods of 100 plants of Broom from Yorkshire were counted. In an Appendix the homotyposis of the seeds in the pods of leguminous plants is dealt with for a number of species. The general result is that homotypic intensity is *halved* when we deal with a character associated with fertilisation.

We then considered two cases in which we knew the growth factors to be very marked. Dr. E. Warren measured the length and breadth of twenty-five leaves of 100 plants of common ivy (*Hedera Helix*) and Dr. Lee and myself the length and breadth of ten gills of 107 Mushrooms (*Agaricus campestris*). The homotyposes of the leaf and of the gill *indices* in these two cases were determined, and form series (21) and (22). The homotypic correlation of the absolute lengths and breadths was also found in order to obtain some measure of the effect of different stages of growth on homotyposis. Omitting the last series of absolute measurements subject to growth, the mean value of the twenty-two series gave the intensity of homotypic correlation as 0·4570.

(3.) A theory of fraternal hereditary resemblance is given on the basis of the likeness of brothers being due to homotyposis in the characters of spermatozoa and ova put forth by the same two individuals and uniting for the zygotes whence the brothers arise. It is found that the mean value of fraternal correlation ought to be equal to the mean intensity of homotypic correlation. We have so far worked out nineteen cases of fraternal correlation in the animal kingdom, and their mean value = 0·4479, *i.e.*, is sensibly equal to the intensity of homotyposis in the vegetable kingdom. It is, therefore, very probable that heredity is but a phase of homotyposis, and that the latter approximates to a certain value throughout living forms.

The theory involves a certain mean relation between direct and cross homotyposis, *i.e.*, that the homotypic correlation between characters A and B in a pair of homotypes is the product of the direct homotypic correlation of A and A (or B and B) and the organic correlation of A and B in the individual. We had only the absolute lengths and breadths of Ivy leaves and Mushroom gills to test this proposition on, and the growth factor is here dominant. The results do not show complete equality, but this is hardly to be wondered at when we consider the extraneous influences at work.

(4.) The individual variation in the twenty-two series was measured and expressed as a percentage of the racial variation ; the results range from 77 to 98 per cent., with a mean value of 87 per cent. If this percentage variation occurs within the individual, it is clearly idle to speak of variation as a result of sexual reproduction. It exists in full intensity when an individual buds or throws off undifferentiated like organs. The blood-corpuscles produced by a single frog are almost as variable as the blood-corpuscles in the whole race of frogs. Thus, variation is established as a primary feature of all vital production whatever.

(5.) No relation whatever could be found between the intensity of homotyposis (and therefore *a fortiori* of heredity) and the degree of variability of the species. If species are classified in order of variability for our twenty-two series, the mean homotyposis of the first eleven is 0·4559 and of the last eleven is 0·4570. No relation whatever, as far as we were able to judge, could be found between the simplicity or complexity of the organisms dealt with and either their variability or their homotyposis. The Mushroom was quite comparable with the Poppy or the Spanish Chestnut. We conclude, accordingly, that there is no evidence at present to show that variation has decreased and heredity increased with the progress of evolution. On the contrary, without laying down any dogma, we should consider the results obtained as consistent with variability and homotyposis being primary factors of the growth of all living forms and not the product of natural selection, but factors upon which its effectiveness *ab initio* has depended. If we can show that homotypic correlation is as intense in the simplest forms of life as in the most complex, and that inheritance flows naturally from it, it is clear that our view of living forms will be considerably simplified. Homotyposis is unfortunately obscured by other factors due to growth, environment, unobserved differentiation, or heterogeneity in one or another form. But the results of this our first investigation in this field seem to support the view just expressed, and to indicate that the Principle of Homotyposis (by which we must again say we mean a *numerical* appreciation of the likeness and diversity among homotypes) is a fundamental law of nature, which will enable us to sum up in a brief formula a great variety of vital phenomena.